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PICK AND PLACE ROBOTIC ARM

KUAN PEI WEN

A thesis submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor of Engineering (Electrical – Mechatronics)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2012

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I declare that this thesis entitled “Pick and Place Robotic Arm“ is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

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DEDICATION

This thesis is dedicated with respect and love to my parents who never stop believing in me and for their eternal encouragement and strong support throughout my journey of education.

ACKNOWLEDGEMENT

In preparing this thesis, I received numerous guidance from many people. A number of them made significant contributions to this thesis. Their insights, advice, suggestions and guidance helped me greatly in completing my final year project.

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Lastly, I will like to thank my parents for their never ending support and encouragement throughout my studies. Thank you for believing in me.

ABSTRACT

Robotic arm is widely used in manufacturing and assembling industries to replace human labour and overcome human inefficiency in performing job tasks. Automated robotic arms are proven to be able to perform well especially in repetitive pick and place task. In this project, a four degree of freedom automated robotic arm with a two finger gripper is developed and built. This robotic arm serve as a solution to replace workers who are assigned to manually pick up hard drive circuit boards one by one and place the circuit boards in trays following the correct arrangement and orientation in manufacturing industry. The hardware, software (programming) and a simple circuitry were designed, built and later integrated to produce a fully automated pick and place robotic arm. This project will serve as a future reference to students who are interested and also for any further development by industries.

ABSTRAK

Lengan robot diguna secara luas dalam industri pembuatan dan pemasangan untuk mengganti buruh manusia dan mengatasi ketidakcekapan manusia dalam menjalankan tugas pekerjaan. Lengan robot automatik telah dibukti boleh memberi prestasi yang baik terutamanya dalam tugas ambil dan letak berulang. Dalam projek ini, lengan robotik berautomatik yang mempunyai empat darjah kebebasan dengan penggenggam dua jari direka dan dibina. Lengan robot ini menjadi penyelesaian untuk mengganti pekerja yang ditugaskan untuk mengambil papan litar tercetak satu demi satu dan meletak papan litar dalam dulang mengikut susunan dan orientasi yang betul secara manual dalam industri pembuatan. Perkakasan, perisian (pengaturcaraan) dan sebuah litar yang mudah telah direka, dibina dan kemudiannya disepadukan untuk menghasilkan sebuah lengan robot ambil dan letak berautomatik. Projek ini akan berfungsi sebagai rujukan kepada pelajar-pelajar yang berminat dan juga untuk penyelidikan dan pembangunan lanjut pada masa depan.

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LIST OF ABBREVIATIONS

SCARA	-	Selective Compliance Automatic Robotic Arm
PCA	-	Printed circuit assembly
RIOS	-	Robotic arm Interactive Operating System
SSC	-	Serial Servo Controller
GUI	-	Graphical user interface
RC	-	Servo Radio
DC	-	Direct current
PIC	-	Printed Integrated Circuit
Approx	-	Approximately

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CHAPTER 1

INTRODUCTION

1.1 Background

In manufacturing and assembling industries, human labour is largely employed to do repetitive task which usually requires precision and accuracy. It is unavoidable that humans will make mistakes while performing a task. Moreover, productivity will be lower as human have limited working hours and work slower. To overcome the human inefficiency, more and more industrial robots are designed and built to accommodate the increasing demands for better productivity, product quality and precision in performing task. Industrial robots come in various types and designs depending on the function and purpose it is build for. These robots reduce labour cost and will become the solution for shortage of workers in future by directly replacing human workers in performing task in industries and other fields of work.

Celestica Inc. is a multinational electronics manufacturing services company. The headquarters of this company is situated in Toronto, Canada. One of the branches in Malaysia is located at the Tampoi Industrial Estate in Johor Bahru. The Johor Bahru team provides its customers with printed circuit assembly (PCA), box build, repair services, systems assembly and test [1]. In Celestica Inc, some of the workers are assigned to manually pick up hard drive circuit boards one by one and

place the circuit boards in trays following the correct arrangement and orientation. Due to slow productivity and human error, Celestica Inc decided to request for an automatic pick and place robotic arm which can replace human workers in performing the previous task mentioned. An automatic robotic arm can perform repetitive task faster with higher precision without stopping.

A robotic arm is a mechanism that is designed and built to resemble and imitate the movement of a human arm. The design and structure of a robotic arm depends on the function and complexity of the task to be performed. Usually robotic arms are more widely used in manufacturing industries that deals with small electronic components where pick and place task is essential. Lynx 5, Type I SCARA and Type II SCARA are some of the robotic arms that were already developed and sold in the market.

1.2 Objectives

The objective of this project is to design and build a four degree of freedom robotic arm with a gripper for pick and place purposes. Besides that, a hardware and software system that can be integrated to support the application system of the pick and place robotic arm will be developed.

1.3 Scopes

The scope of the project is to construct a robotic arm with 4 revolute joints to pick a rectangular item with the dimension of 4cm x 3cm x 3cm from a fix position A to another designated position B. The item to be picked will resemble a hard drive circuit board but in a smaller and lighter version.

1.4 Problem Statement

Below are the problems encountered while designing and constructing the robotic arm:

(i) Unable to pick up a real hard drive circuit board due to the limited torque of the robotic arm motors.

(ii) The actuator used has limited torque. A robot arm structure that is bulky and heavy will wear out the actuators due to overloading.

(iii) Constraints in the robotic arm design due to limited rated torque of the actuators.

(iv) Difficulty in programming the RC servomotors to the desired position as each of the motors has a slightly different angle or rotation with the same given input.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The research conducted on previous theses, journals, articles, research papers and other sources will be presented in this chapter. The main idea of literature review is to obtain enough relevant information and knowledge on similar projects done by others. A few projects done previously by students and researchers will be discussed here.

2.2 Previous Projects

For the past years, many have attempted to design, create and construct robotic arms using different approaches. Below are some of the projects which are closely related to the concept of a pick and place robotic arm.

2.2.1 Lynx 5 Programmable Robotic Arm Kit

Lynx 5 is one of the successful robot arm build by Lynxmotion which is already sold in the market with popular demands. It is build for repeated, fast and accurate movements. This robotic arm has 4 degrees of freedom that allows rotation at the base and motion at the shoulder, elbow and wrist. The kit comes along with a two finger gripper.

The structure of the robotic arm is made from ultra-tough laser-cut Lexan structural components, black anodized aluminium servo brackets, and custom injection moulded components [2]. For motion at each joint of the arm, servo motors are used. Hitec HS-422 servo motor is used for all the joints except the gripper where HS-81 is used. Figure 2.1 shows the structure of the Lynx 5 robotic arm.

A pre-assembled Mini SSC-II servo controller controls the motion of the servo motors by providing control pulses to servos after receiving position commands from a computer. The robotic arm can be taught to have a sequence of movements using RIOS (Robotic arm Interactive Operating System) with a mouse or joystick. For better arm positioning, inverse kinematic is applied in this robot. The software used is a DOS software written in Quick BASIC version 4.5.

This robotic arm has an interesting structural design which can serve as a reference. The design is simple and not too bulky for a robotic arm with four degrees of freedom. On the other hand, Mini SSC-II servo controller can be replaced by microcontroller for easier implementation and better actuator control.

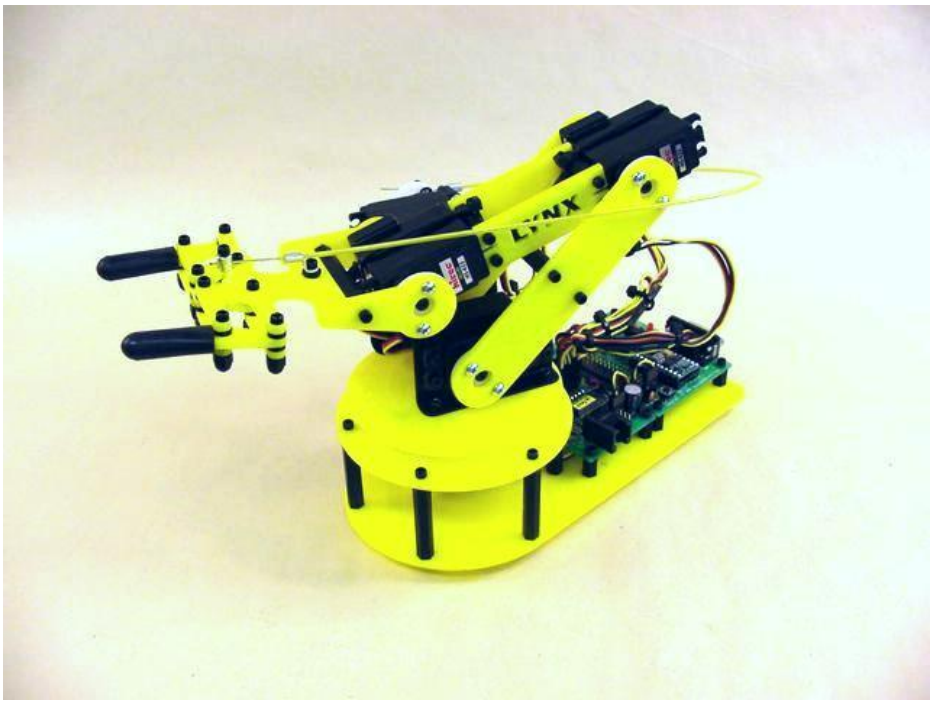

Figure 2.1 Lynx 5 Programmable Robotic Arm

2.2.2 Robotic Arm with Image Processing

This is a robotic arm done by Sam Men Wee, a student from Universiti Teknologi Malaysia in year 2009. The core idea of this project is to construct a 6 degree of freedom robotic arm that can emulate the movements of a human arm successfully with the assistance of image processing application. The wanted outcome is to use the robot arm to help human in daily chores.

Since the robotic arm is built to emulate as closely as possible the motion of a human arm, all joints constructed are revolute joints. The shoulder part has three degrees of freedom with three joints constructed in revolute configuration for the positioning of robot wrist. Another three revolute joints are designed for yam, pitch and roll movement at the wrist. A two finger gripper is attached as the end effector.

Figure 2.2 illustrates the complete hardware structure of the robot arm.

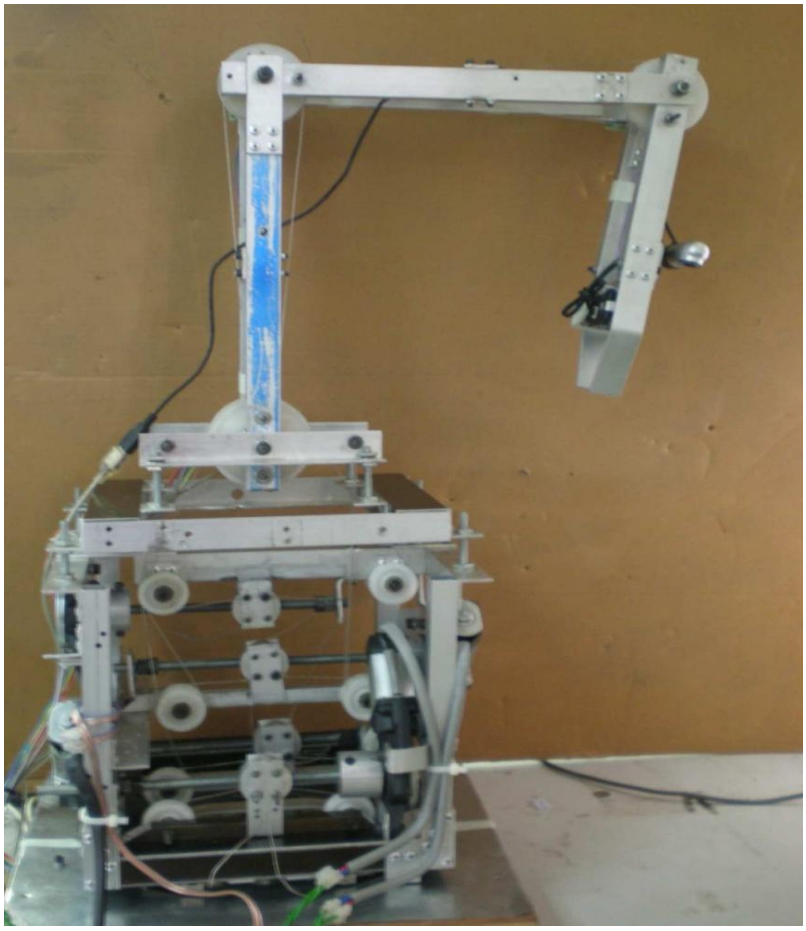

Figure 2.2 Completed robotic arm hardware structure by Sam Men Wee

In this project, robot kinematics is used to compute each robotic arm joint position and dynamics deals with its movement that takes into consideration of mass and inertia. Path planning is also used in interpolating robotic arm movement from one point to another point. Moreover, a camera is attached to the robotic arm, and image processing is employed to extract image data and features that can eventually help the robotic arm recognize the object in its presence [3].

Windows graphical user interface (GUI) is important for the simulation of the robotic arm and the result is displayed in 3D where the current arm position and

movement will be shown. GUI is also used to monitor the robotic arm status. The remote control interface via Bluetooth device is an extra feature for the robotic arm.

The idea of using image processing to help the robot recognize object targets enables the robot arm to pick up a specific item with better efficiency and higher accuracy. However, the high degree of freedom complicates the mechanical structure. The 6 degrees of freedom used in this project increases the complexity of the control algorithm and kinematic control. Complexity in inverse kinematics leads to the inaccuracy of link angle position given by the mechanism.

2.2.3 Competitive Low Cost Robot Arm

This low cost robot arm was developed by a group of researchers from different countries and universities. The objective of this work is to design, develop and implement a competitive low budget robot arm with enhanced control. The robot arm is develop to handle or pick and place light material which can later be used as an assistant for industrial workforce.

According to their research, a basic structured robot arm should be limited to 4 degrees of freedom because such a design allows most of the necessary movements and at the same time keeping the costs and the complexity of the robot competitively low. Thus, this project implements the idea of a 4 degrees of freedom robotic arm where all the joints are revolute. Acrylic material was used to build the robot arm and servo motors were used to execute arm movements. Controllers were replaced by servo motors with encoders in this project. Hextronik HX12K servo motors are responsible for joint movements at the shoulder, elbow, wrist, and base. A two finger commercially available gripper was chosen as the end effector. Figure 2.3

shows the free body diagram of the robot arm whereas Figure 2.4 illustrates the actual hardware structure.

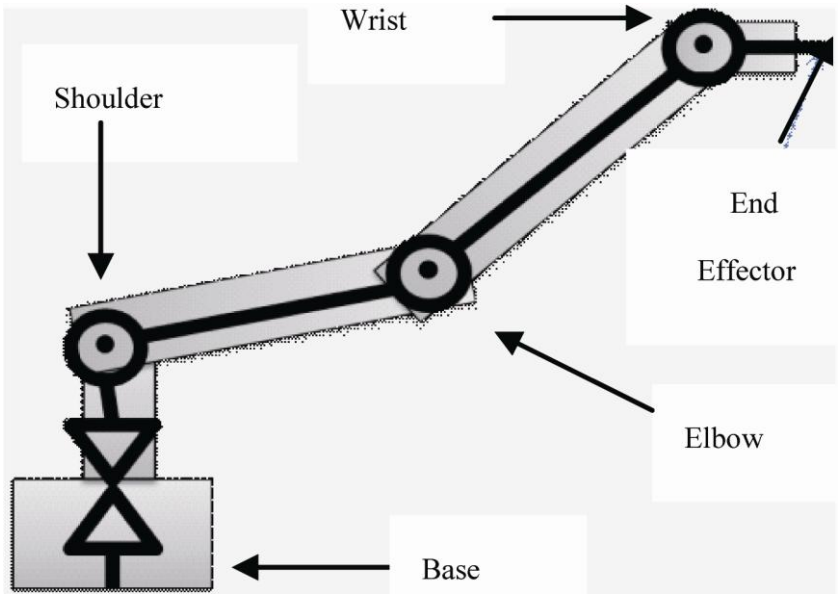

Figure 2.3 Free body diagram of robot arm

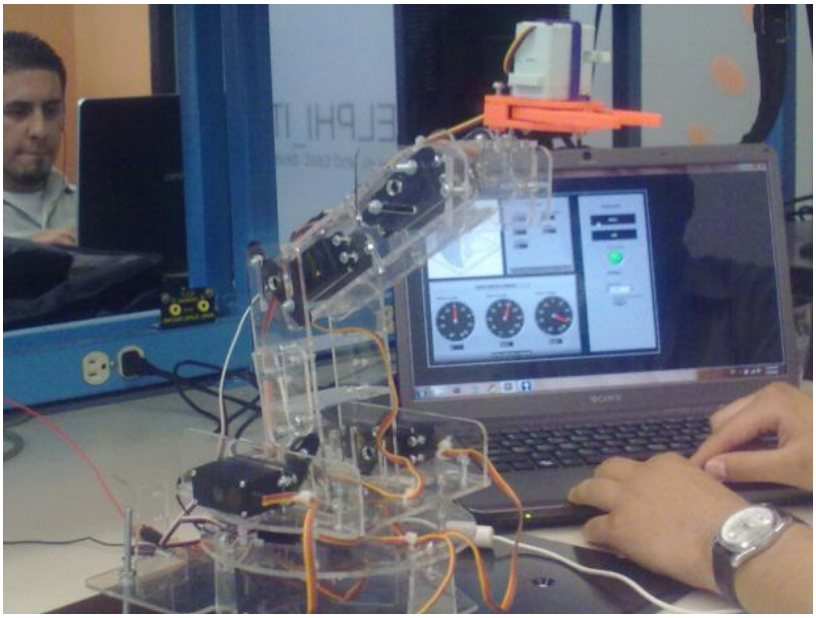

Figure 2.4 Actual hardware structure of robot arm

To control the robot arm, an Atmega 368 with an "Arduino" development/programming board microcontroller, a six-channel Micro Maestro servo controller board driver and a computer-based user interface was integrated to form a working system for robot arm movement. Moreover, Labview performs inverse kinematic calculations and communicates the proper angles serially to a microcontroller that drives the servo motors with the capability of modifying position, speed and acceleration [4]. As an addition feature, this robot arm can function fully in manual mode. Users can switch to manual mode when the inverse kinematics calculations become too complicated.

This research paper suggests the use of 4 degrees of freedom for simple robotic arm. It is a good suggestion as the complexity of the structure, kinematics calculation and algorithm will be lower. Using lower degree of freedom can reduce the cost of developing a robotic arm as well.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is about the entire flow and methods implemented to complete the project. It includes information and explanation on the basic mechanical structure to the final stage where testing and tuning takes place. The project is divided into three parts which are mainly the hardware construction, circuit development and software programming. Main components used will also be elaborated here. Figure 3.1 shows the complete system design.

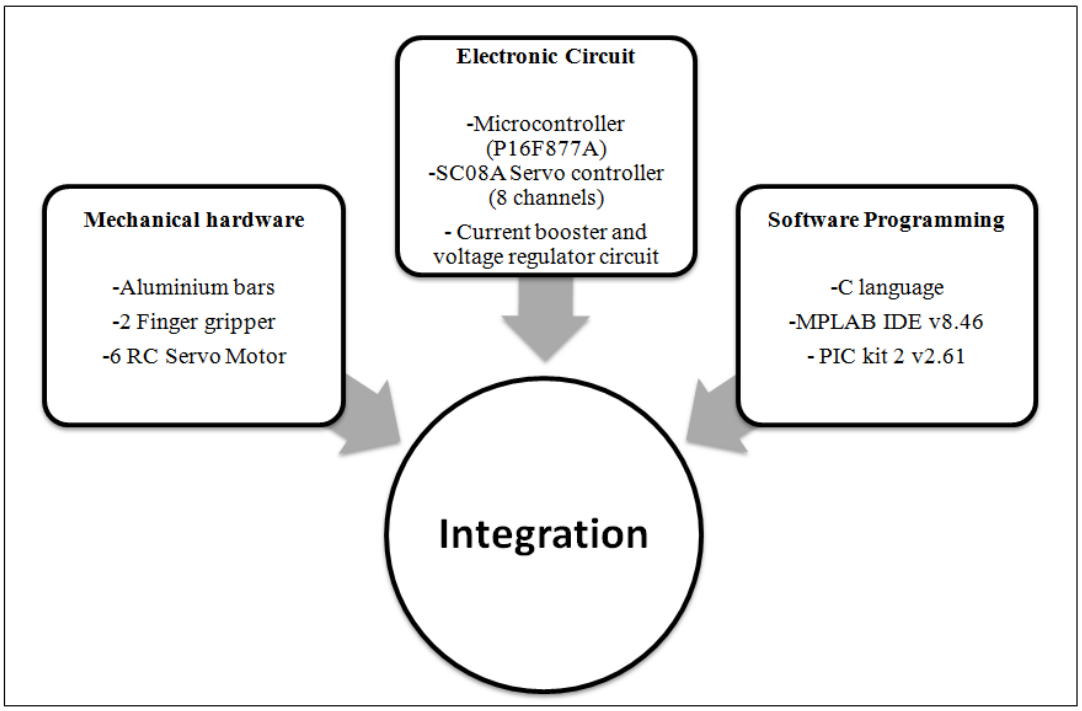

Figure 3.1 Complete system design

3.2 Project Flow

A successful project requires good planning before implementing any part of the project. Project flow is the tasks arranged in sequence planned for the project. Here, the project started with literature review whereby articles, journals and research papers were read to obtain necessary information before carrying out the project. After getting sufficient background knowledge on theories and concept, hardware and circuit design will be develop. Designs will be drawn using software like Google SketchUp 8. The designs will be based on the requirements and functions stated in previous chapters. Based on the designs developed, construction of the hardware and circuit will be executed. Then, the project will proceed to the hardware and software integration. This will be the hardest part and more time will be required here. After successfully combining and integrating all the necessary parts, the robot arm will be tested and tuned. If the robotic arm functions as desired,

the project is successful and work will stop here. However if it has errors or complications, software and hardware integration have to be carried out all over again. Figure 3.2 shows the simplified project flow chart.

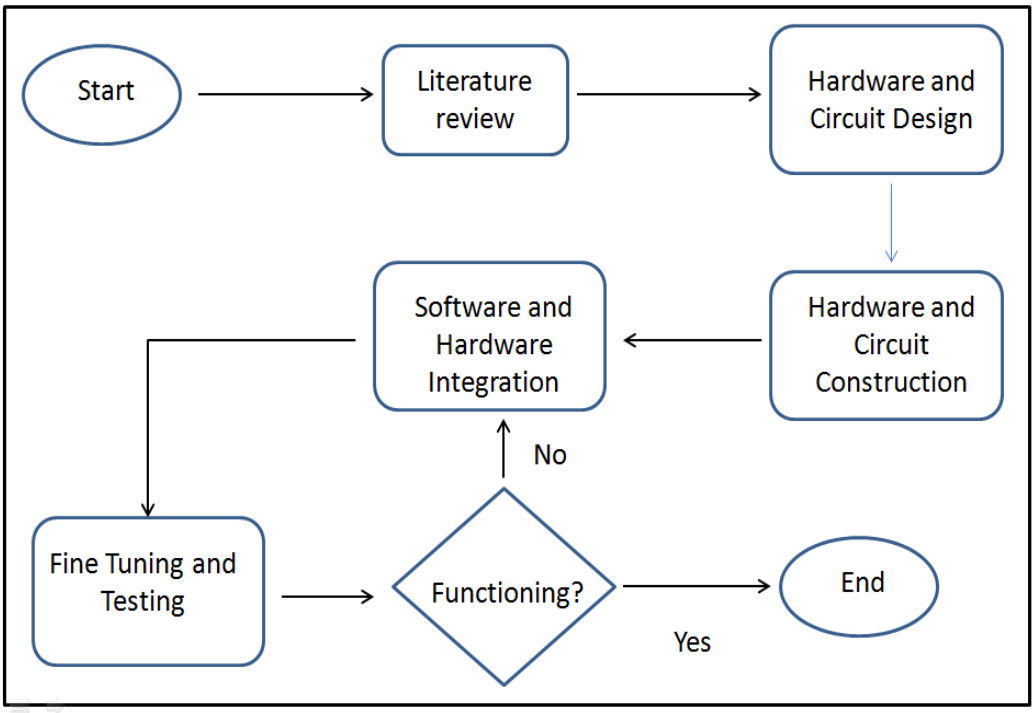

Figure 3.2 Simplified project flow chart

3.3 Mechanical Hardware

Mechanical hardware includes the structure of the robot arm from the base, links to the 2 finger gripper as the end effector. The materials used to build the main frame of the robot arm are aluminium links and bars. The choice of materials is due to the availability, lower cost and weight.

3.3.1 Robotic Arm Design

The robotic arm is designed for simple pick and place purposes. The robotic arm will pick an item from a fix point and place it at another fix point. Thus, a simple structure with four degrees of freedom is sufficient. This design has four revolute joints which is located at the base, shoulder, elbow and wrist. These four joints emulate the motion of a human arm. In this project, only two links will be used. A two finger gripper will serve as the end effecter. Due to time constrain and the complexity to build a gripper, a commercially available gripper was used for this project. For motion and movements of the joins, actuators like servo motors are considered. A radio control servo motor is attached to every joint of robotic arm. Figure 3.3 shows the preliminary sketch of the robotic arm design using Google SketchUp 8.

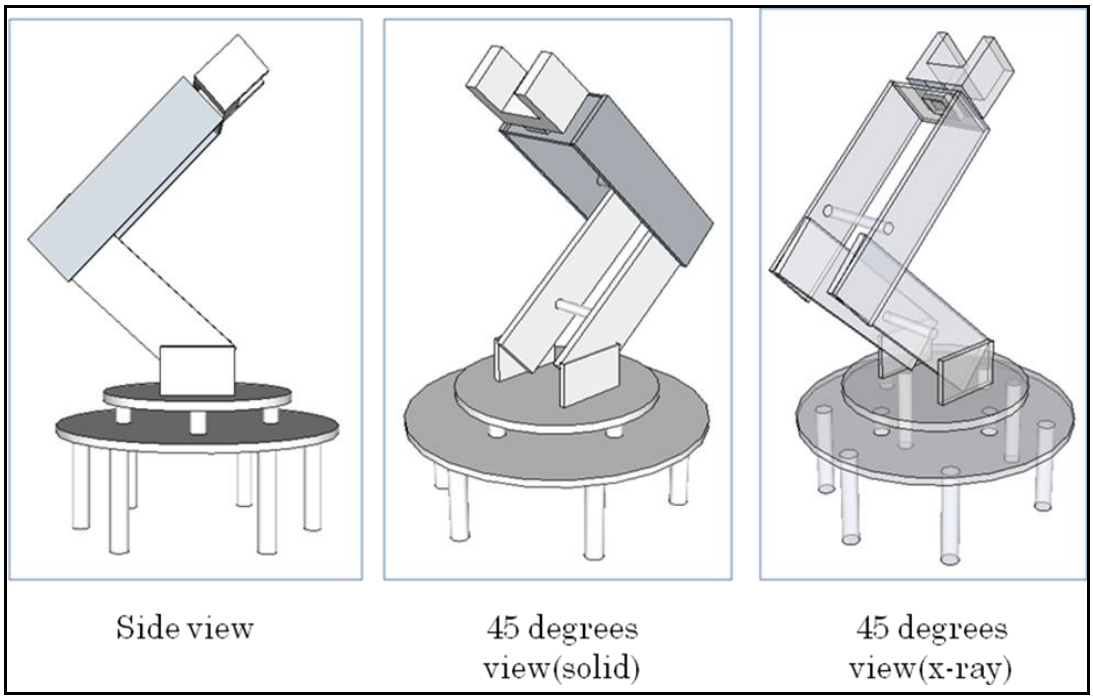

Figure 3.3 Preliminary robotic arm design in different angle views

3.3.2 Two Finger Gripper

A two finger gripper will serve as the end effector for this project. A gripper set that comes with a medium size metal gear servo was purchase from Cytron Technologies Sdn Bhd. This gripper is made from metal and can pick up some relatively heavy objects. The claws open to about 2 inches depending on the servo motor used. Since the two fingers move parallel to each other, a better grip is acquired. However, this gripper set is not assembled. It has to be assembled by the user. The components that come with the set are not a perfect fit. Thus, a few modifications have to be made so that the gripper can function nicely. This gripper will be attached to the actuator at the wrist of the robot arm. Figure 3.4 shows how the gripper looks like.

Figure 3.4 Image of 2 finger gripper

The medium size metal gear servo has the following features [5]:

i) 180 degree rotation
ii) Operating Voltage: 4.8V~6.0V
iii) Operating Speed: 0.18sec/60degree (6V)
iv) Output torque: 3.2kg/cm (6V)
v) Dimensions: 28.8 x 13.8 x 30.2mm

3.3.3 Radio Control Servo Motor

RC hobby servos are compact, low cost and great actuators for robots. The popularity in using RC servo motors in the robotics field is due to its ability to rotate and maintain at certain location, position or angle according to control pulses from a single wire [6]. A RC servo motor comes with a gearbox and small motor to enable motion. The electronic circuit embedded in the RC servo motor controls the motor so that the output gear will move to the desired position. In short, the main reason for choosing RC servo motors as actuators for joint movements is because they are DC motors with built in gearing and feedback control loop circuitry where no motor driver is needed. Degree of rotation for a servo motor is controlled by Pulse Width Modulation. Figure 3.5 illustrates the selected type of RC servo motor.

Figure 3.5 C55R RC servo motor from Cytron

Specification for C55R RC servo motor:

i) Full Metal Gears
ii) Suitable for heavy duty application
iii) 2 Ball Bearings
iv) Speed (sec/60deg): 0.22/4.8V, 0.20/6.0V, 0.17/7.2V
v) Torque (Kg-cm): 9.0/4.8V, 11.0/6.0V, 13.0/7.2V (maximum 7.2V)
vi) Size (mm): 40.8x20.18x36.5
vii) Weight (g): 55
viii) Rotation angle: 180 degree
ix) Pulse width range: 0.582ms to 2.5ms (estimation)

In this project, a total of 5 servo motors are used. A servo motor is attached to the base, elbow and wrist for rotational or link movements. For the shoulder joint, two servo motors are used because more torque is needed to support the heavy frame of the robotic arm at that joint.

3.4 Circuit Development

In this section, mainly the microcontroller and position sensor used will be discussed.

3.4.1 Microcontroller

Microcontrollers are like mini computers that can be fit into robots. For a robotic arm, microcontroller is the master brain that controls all the joint movements and determines the next step to be executed. PIC 16F877A, a powerful 200 nanosecond instruction execution yet easy-to program CMOS FLASH-based 8-bit microcontroller produce by Microchip Technology Inc is selected to be used in this project [7]. This microcontroller is cheap and easy available in the stores. It has suitable functions and enough output pins for a robotic arm with 5 servo motors. The 8 channels of 10-bit analogue to digital converter is an important function for converting the analogue output voltage received from potentiometer to a digital signal. Figure 3.6 shows the image of a PIC 16F877A and Figure 3.7 shows the schematic diagram of the PIC.

Figure 3.6 PIC 16F877A

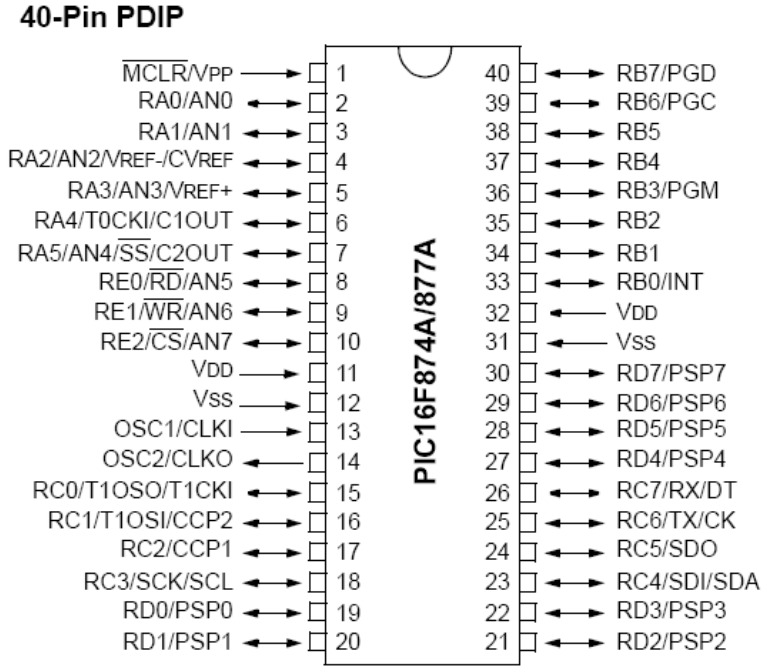

Figure 3.7 Schematic diagram of PIC 16F877A

Below are the important features of PIC 16F877A:

i) Pin Count: 40-pin PDIP
ii) Program Memory: 14KB or 8K 14-bit Flash
iii) Max Crystal Speed: 20MHz
iv) RAM Bytes: 368
v) EEPROM Bytes: 256
vi) Timers: 2 x 8 bit, 1 x 16-bit
vii) Digital Communication: 1xA/E/USART, 1 x MSSP(SPI/I2C)
viii) Capture/Compare/PWM: 2 x CCP
ix) ADC: 8ch, 10-bit
x) Comparators: 2

3.4.2 Enhanced 40 Pins PIC Start-Up Kit (SK40C)

This start- up kit is designed to offer an easy to use starter board for PIC microcontroller users. It comes with basic element for users to begin project development and offers plug and use features [8]. No extra components are required for the PIC to function thus saving development and soldering time [9]. A 12volts 0.5ampere adapter will be use to power this board. Only the UART pins will be used to connect to the servo controller board. Figure 3.8 illustrates an image of SK40C.

Below are some of the important features that this start-up kit offers:

i) ICSP connector for UIC00A -simple and fast method to load program.
ii) Perfectly fit for 40 pins 16F and PIC18F PIC.
iii) 2 x programmable switch.
iv) 2 x LED indicator.
v) 20MHz crystal oscillator.
vi) UART connection to interface with other controller or even computer.
vii) Users are able to utilize the function of PIC by directly plugging in the I/O components in whatever way that is convenient to user.

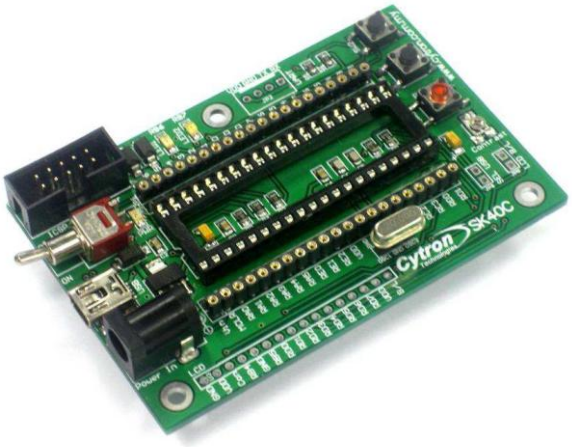

Figure 3.8 SK40C

3.4.3 8 Channels Servo Controller (SC08A)

This servo controller can control up to 8 channels of servo motors simultaneously and independently. Each servo signal pin can generate 0.5ms to 2.5ms servo pulses. Thus, servo motors can have an angle of rotation from 0 to 180 degrees. In addition, this servo controller has a resolution of 8000 steps which is equivalent to 0.25ms servo pulse. The servo pulse is controlled by simply manipulating the resolutions while writing the program to control the servo motor movement. Besides this, user can activate or deactivate any servo channel of choice. Moreover users are free to set the initial position of any servo channel for the next start-up. This feature is very useful in this project since each servo motor has different initial position at start-up. Another function of this servo controller allows user to request the position of an individual servo. The UART here has a 9600 baud rate. On the other hand, the small design of this board is very useful. This board has the dimension of 49mm x 46mm. It is also possible to extend up to 16 channels by linking together two 8 channel servo controller. Figure 3.9 shows an image of SC08A. S1 to S8 are the 8 channels where the servo motors will be connected. SC08A has a separated power source for the PIC operation and for powering the servo motors. The pins RX, TX, GND and 5V are used for UART connections to the SK40C.

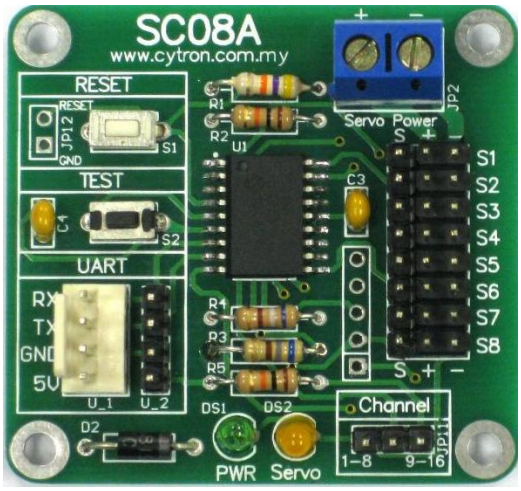

Figure 3.9 SC08A

3.4.4 UART

Universal Asynchronous Receive/Transmit abbreviated UART is known as a piece a piece of computer hardware that translates data between parallel and serial forms [10]. However in the context of robotics, it is better known as a useful device for communicating serial data between microcontroller and computer. UART changes incoming parallel information to serial data which can be sent on a communication line [11]. For this project, UART is use to send data between the microcontroller and the servo controller. The data sent each time is the size of one byte. A minimum of 5volts supply is required for microcontroller to interface with SK08A. Figure 3.10 shows the schematic diagram of the connection between SK40C to servo controller using UART interface.

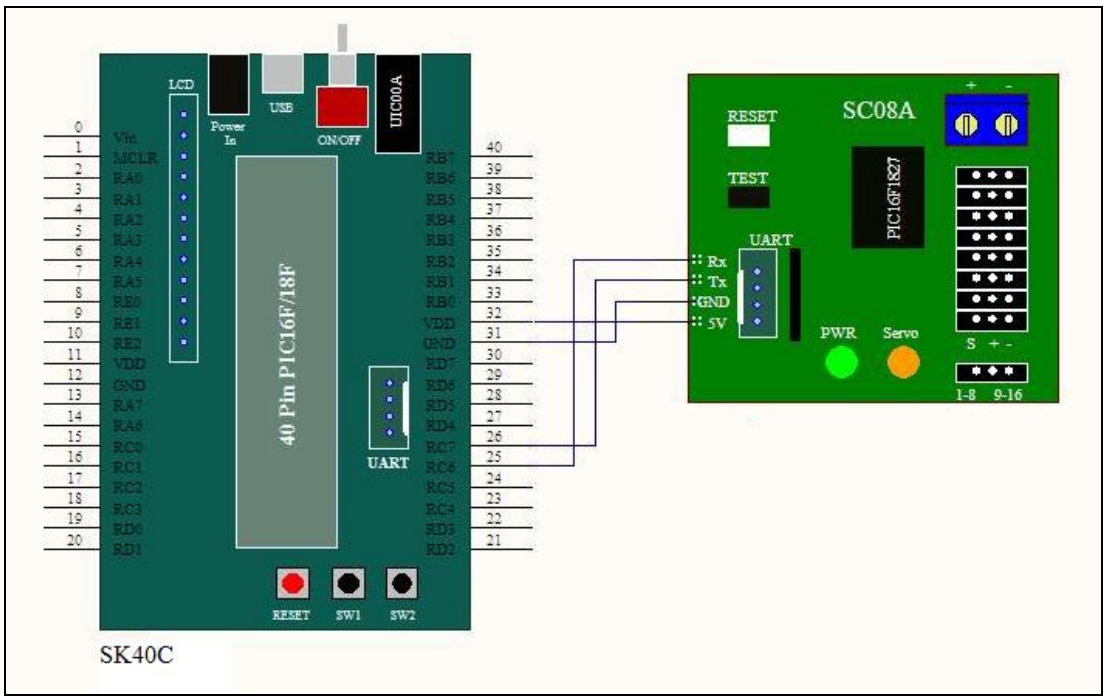

Figure 3.10 Schematic diagram of UART interface

3.4.5 Current Booster and Voltage Regulating Circuit

This circuit plays a major role in supplying a constant 6.09V and approximately 2.67A to the servo motors. The power source for this circuit is from a 12V and 2A adapter source. In this circuit, LM7806 provides a constant and regulated output of 6.09 volts. As for the power transistor (TIP 2955), it is used to boost the extra needed current above the maximum allowable current provided via the regulator. Current up to 1.5A will flow through the regulator, anything above that makes the regulator conduct and adding the extra needed current to the output load [12]. Due to the high current drawn by servo motors, components such as regulator and power transistor will be very hot. Thus, to reduce the heat generated, these components must be mounted on heat sinks. Figure 3.11 shows the schematic diagram of the current booster and voltage regulating circuit.

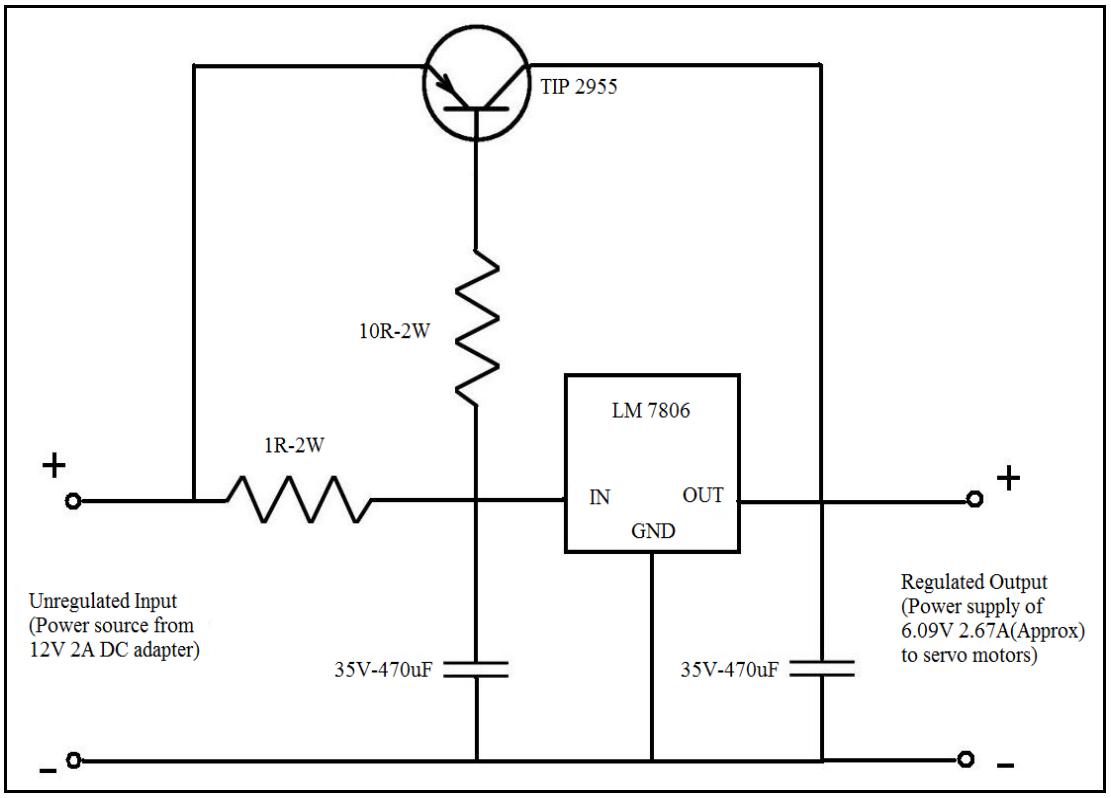

Figure 3.11 Schematic diagram of current booster and voltage regulating circuit

3.4.6 Power Source

Two AC-DC adapters are used to power this project. A 12V 0.5A adapter is used to supply power to the SK40C. A 5Vsupply will be supplied from the SK40C to servo controller for PIC operation through UART interface. Another adapter which supplies the 12V 2A will be connected to the current booster and voltage regulating circuit. The regulated output power supply from this circuit will then be fed into the servo controller to power the servo motors. Figure 3.12 illustrates the 12V 0.5A AC-DC adapter while Figure 3.13 shows the 12V 2A AC-DC adapter.

Figure 3.12 12V 0.5A AC-DC adapter

Figure 3.13 12V 2A AC-DC adapter

3.5 Software Programming

MPLAB IDE software is used to write programs to control the movement of the joints. MPLAB Integrated Development Environment (IDE) is a free, integrated Gcc-based toolset for the development of embedded applications employing Microchip's PIC [13]. MPLAB IDE supports both assembly and C programming languages.

3.5.1 Flow Chart for Programming

Figure 3.14 shows the flow chart to program the pick and place robotic arm movements to pick an item from the first position and release the item at the second position.

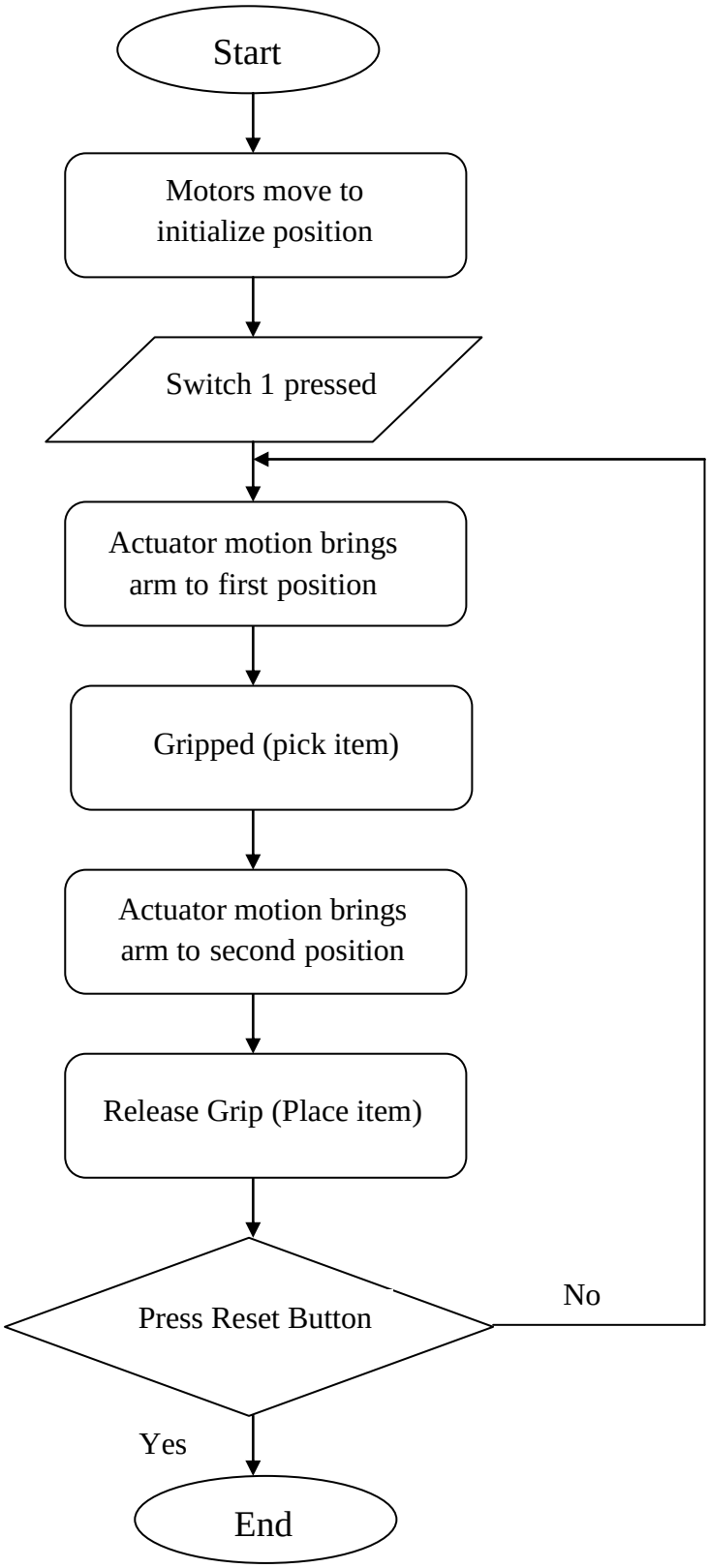

Figure 3.14 Programming flow chart

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this section, the overall results for the project will be presented and explained. The results include the actual structure, circuitry and programming source code. The pick and place process done by the robotic arm will also be shown step by step.

4.2 Actual Robotic Arm Structure

Figure 4.1 illustrates the Actual structure of the robotic arm. The robotic arm is build from aluminium bars and uses PCB stands to raise up the base.

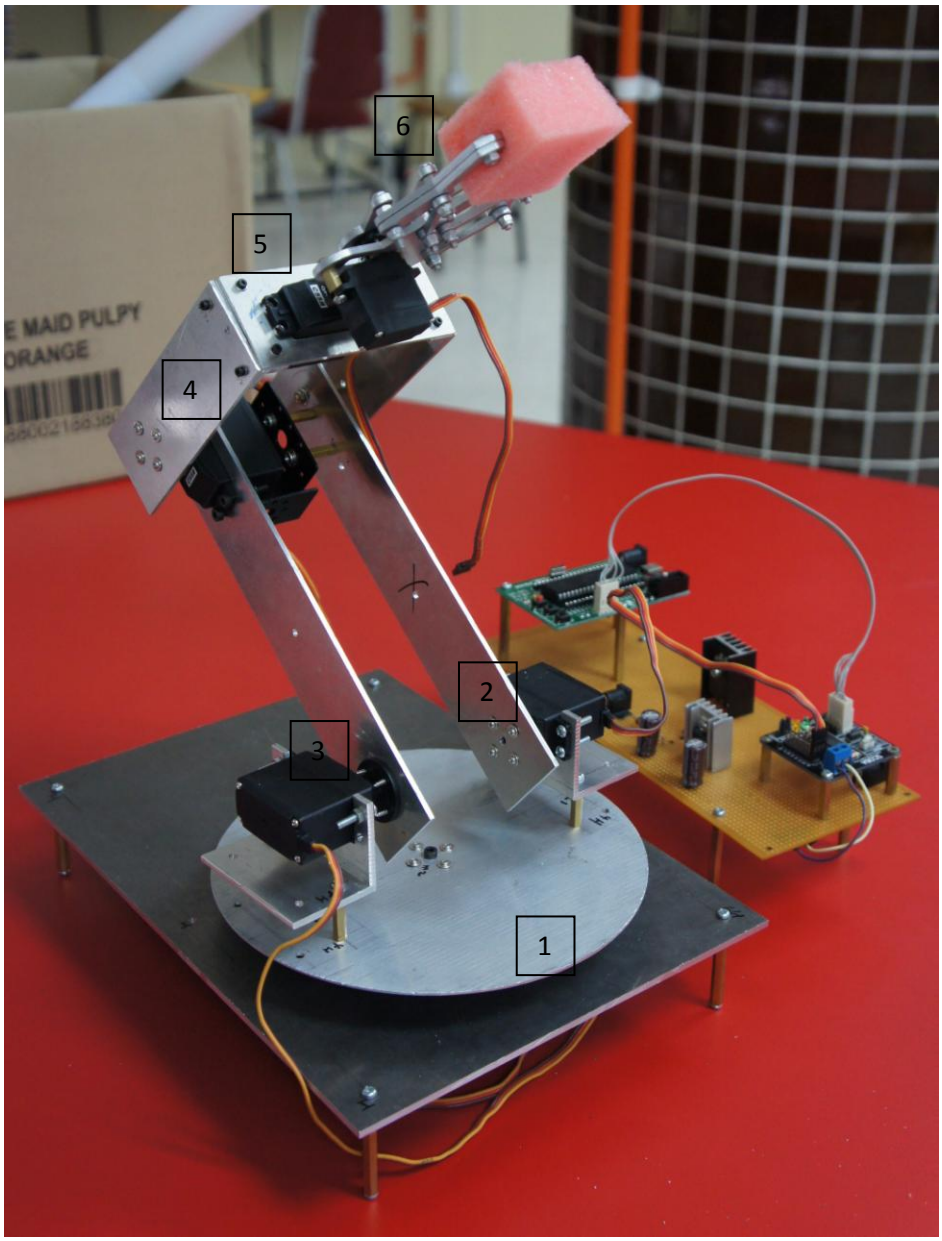

Figure 4.1 Actual robotic arm structure

1 – Rotating base (one servo motor for base rotational motion).

2 – Left panel for the first link (one servo motor for up-down shoulder motion).

3 – Right panel for the first link (one servo motor for up-down shoulder motion).

4 – Second link (one servo motor for up-down elbow motion).

5 – Wrist (one servo motor for rotational wrist motion).

6 – Two finger gripper (one servo motor to grip and release grip operation).

4.3 Complete Circuitry Design

The finalized circuitry design will be presented here. The complete circuit consist of one SK40C with one PIC 16F877A, one servo controller board, one current booster and voltage regulating circuit and a UART connection. Figure 4.2 shows the complete circuit for this project.

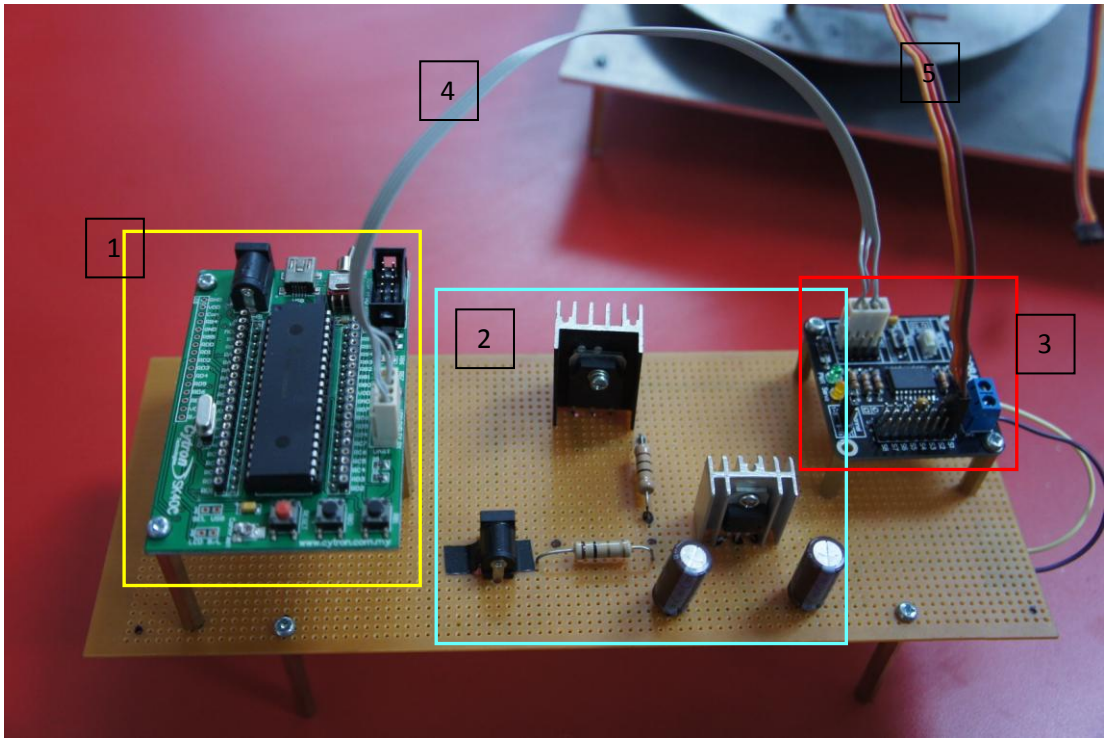

Figure 4.2 Complete circuit

1 – SK40C with PIC 16F877A.

2 – Current booster and voltage regulating circuit.

3 – Servo controller.

4 – UART interface.

5 – Three pin terminals to connect servo motor to servo controller.

4.4 Complete Programming Source Code

The written programming source code for the robotic arm movements is included at Appendix B. Please refer to Appendix B for more details and explanations.

4.5 Pick and Place Routines

After completing the hardware, software and circuitry, the final procedure is integrating all of them into one complete working system that can perform a pick and place routine. The item to be picked and placed is a blue sponge with the dimension of 4cm x 3cm x 3cm. The blue sponge surface with the white marking represents the initial orientation of a PCB from the top view. Aside from being able to do the pick and place routine, the wrist of the robot arm can rotate the sponge 180 degrees to change to orientation of the sponge. At this point, the back view of the sponge (representing the back view of the PCB) will be flipped to the top view.

Figure 4.3 shows the complete pick and place routine. Figure 4.3(1) shows the random position of the robot arm before start-up. In Figure 4.3(2), the robot arm moves to the preset initial position at start-up. After start-up, as shown in Figure 4.3(3), the robotic arm will move to the first position where the sponge with the white marking surface is located to pick up the sponge. The gripper will open slightly and then gripped the sponge. After the sponge is picked, the robotic arm proceeds and moves to the second position. While moving to the second position to place the sponge, the wrist actuator will rotate the gripper at 180 degrees to change the orientation of the sponge. This is shown in Figure 4.3(4). In Figure 4.3(5), the sponge with the altered orientation is placed at the second location. At this point, the

gripper will release grip to drop and place the sponge at the second location. This routine will continue until the reset button on SK40C is pressed. When the reset button is pressed, the pick and place robot arm will stop functioning and return to initial position.

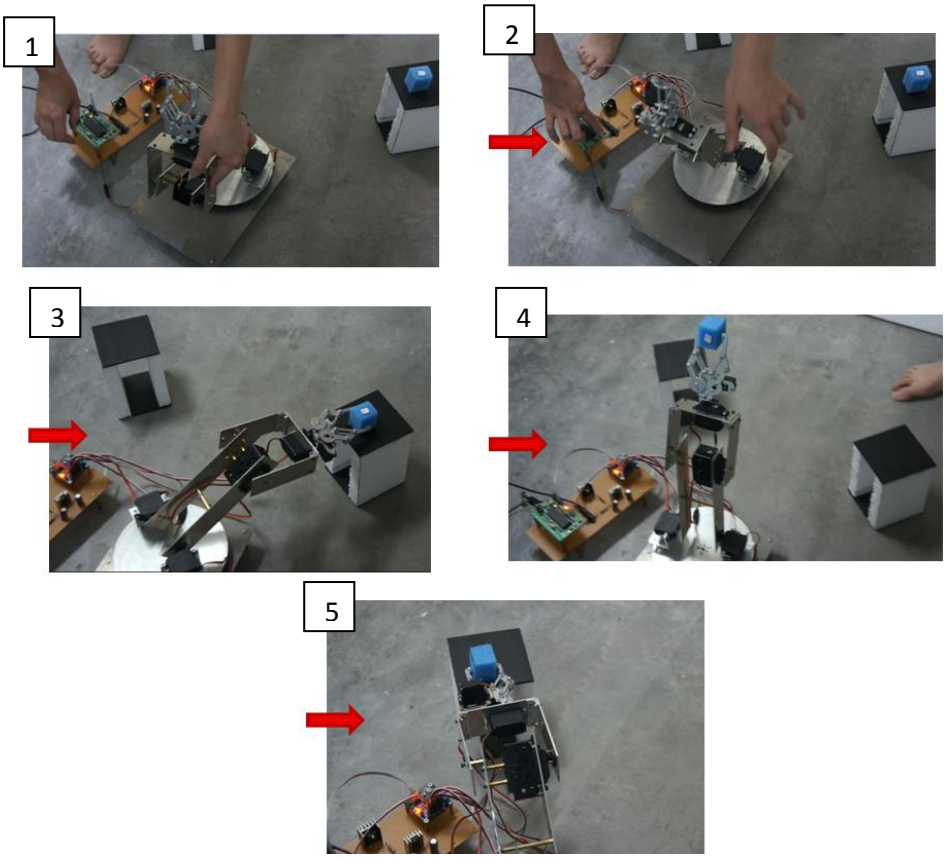

Figure 4.3 Pick and place routine

CHAPTER 5

CONCLUSION

5.1 Conclusion

In conclusion the objectives of this project are accomplished. A four degrees of freedom automated robotic arm with a 2 finger gripper for pick and place purpose was successfully developed and built. Throughout this project, problem solving skills were put to use to overcome any hardware, software or circuitry problems that arise. This project provides analytical skills training, hardware assembly training, program writing training and circuitry design training. The hands on experiences acquired from this project are valuable and will definitely be useful in future.

Generally, this project gives students a chance to incorporate robotic theories and application into their projects. Future developments on projects related to the robotic studies are a must to further enhance the robotic field in our country and bring the robotic field to a whole new level internationally.

5.2 Recommendations

Even though the project is a success, there are a few limitations that can be further improved to develop a better and more robust automated pick and place robotic arm.

i) Hardware. Usually students opt to handmade their mechanical hardware by themselves to safe cost. However, the structure build by students are mostly based on assumptions without solid test and research. This results in the lack of accuracy in the dimension and structure of the robot arm. Students can try to incorporate off-the-shelf hardware structure into their own design for a more solid and accurate hardware design.

ii) Actuator. The actuator used in this project is the RC servo motor. This servo motor is limited to certain torque. Thus, it is actually not suitable to be chosen for this project. However due to lower cost, many students chose to use this type of motor. For future projects, more advance motors like digital servo and stepper motor is advice to be used to provide more flexible, accurate and precise movements.

iii) Controller. Better and more advance controller like PID controller can be implemented in the project.

iv) Sensor. A sensor can be place at the fingers of the gripper to detect whether the gripper is gripping the item or not. This can be a safety function to stop the robot arm function if the item that is supposed to be gripped is dropped.

v) Image processing. Image processing can be included to enable the robot arm to detect and change the orientation of the item to the wanted orientation by itself. A more advance pick and place robot arm can be developed though this.

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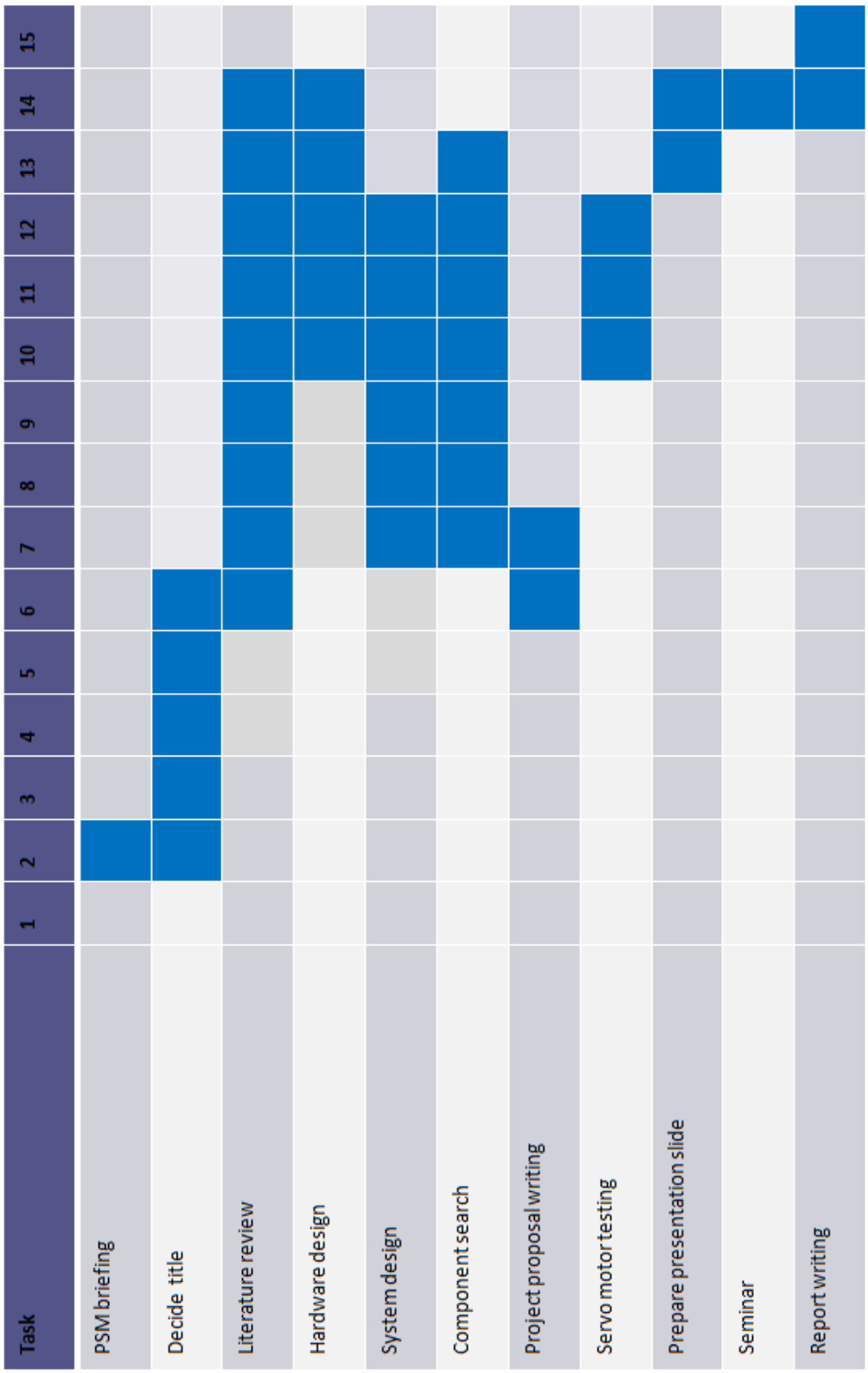
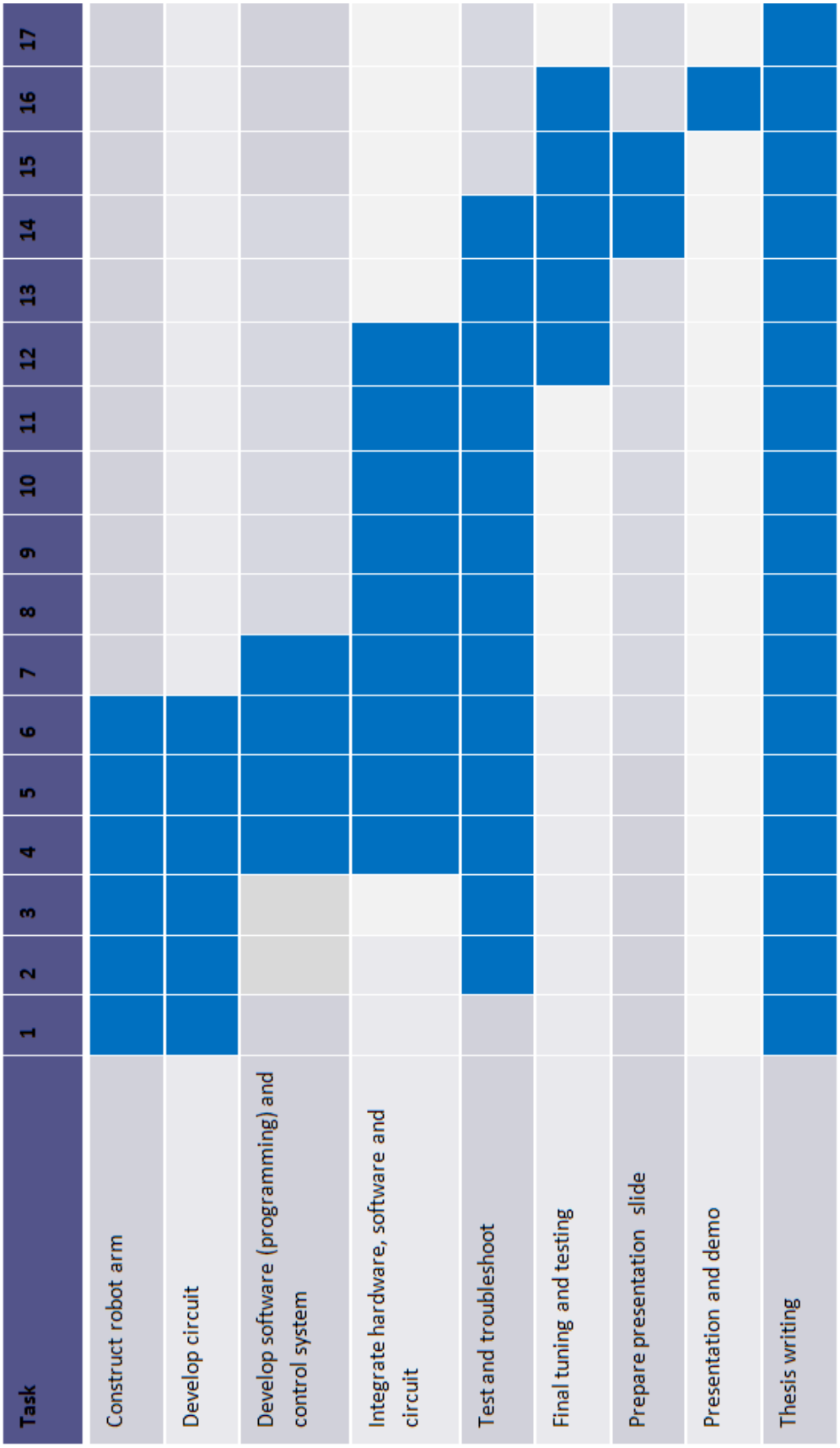
APPENDIX A1 Gantt Chart for Semester I 2011/2012



APPENDIX A2 Gantt Chart for Semester II 2011/2012



APPENDIX B Programming Source Code

```
// include
//======================
# include <pic.h>

// configuration
//======================
__CONFIG (0x3F32);

// define
//======================
#define SW1             RB0
#define SW2             RB1

#define LED1   RB6
#define LED2   RB7
#define SER             RB2

// function prototype
//======================
void init (void);
void init_servo_position (unsigned char channel, unsigned int position);

void on_off_cmd ( unsigned char channel, unsigned char on_off);

void delay (unsigned long time);

unsigned char uart_rec(void);
void uart_send (unsigned char data);

void position_speed ( unsigned char channel, unsigned int position, unsigned char
speed);

void patternrec();

int pattern = 0;

// initialization
//======================
void init ()
{
```

```
	// set I/O port for switchs and LEDs
	//==========================
	TRISB=0b00000011;		// 1 for input, 0 for output
	TRISD=0b00000000;

	// uart initialization
	//==========================
	SPBRG=129;			// baud rate set as 9600 for crystal with 20Mhz
	BRGH=1;				// high speed option for baud rate
	SYNC=0;				// asynchronous mode
	CREN=1;				// enable reception
	SPEN=1;				// enable serial port
	TXEN=1;				// enable transmission
	TX9=0;				// 8-bit transmission
	RX9=0;				// 8-bit reception

	LED1 = LED2 = 1;
	delay(80000);
	LED1 = LED2= 0;
	delay(80000);

	on_off_cmd (0,1);

}

void init_servo_position (unsigned char channel, unsigned int position)
{
	LED1=1;
	LED2=0;

	unsigned char first_byte=0,	higher_byte=0, lower_byte=0;

	first_byte=0b10000000|channel;

	higher_byte=(position>>6)&0b01111111;		//position value from 0-
8000 are greater than a byte
	lower_byte=position&0b00111111;

	uart_send(first_byte);
	uart_send(higher_byte);				//second byte is the
higher byte of position 0b0xxxxxx
	uart_send(lower_byte);


	while (uart_rec()!=0x04)		//wait the 0x04 value from SC08A
			{
				RB2=1;
```

```
                        delay(2);
                        RB2=0;
                        delay(18);
                }

}

void main ()
{


        init();

        //initial position of all the servo motors at start-up

        init_servo_position (8, 3750);  // rotating base
        init_servo_position (6, 1875);  // right panel for first link
        init_servo_position (5, 5000);  // left panel for first link
        init_servo_position (3, 3750);  // 2nd link
        init_servo_position (2, 3750);  // wrist rotation
        init_servo_position (1, 1500);  // gripper


        while(1)
        {
                patternrec();

                while(pattern==1)
                {
                LED1=0;    // LED to show which part of the program the robot arm is
doing
                LED2=1;

                // 1st position
                position_speed (8, 1875, 50); // channel 8 (base rotate to 45)
                delay(250000);

                position_speed (5, 1250, 15); // down(first link go down)
                position_speed (6, 5625, 15);
                delay (250000);

                position_speed (2, 0, 30);   //wrist move to 0
                delay (450000);


                position_speed (3, 2500, 20); // 2nd link go down to 60
                delay (300000);
```

```
position_speed (1, 900, 30); // grip open
delay(200000);
position_speed (1, 2100, 40); // grip close. smaller d number, bigger
the gap.
delay(200000);


position_speed (3, 3750, 20); // 2nd link go up to 90
delay (200000);

position_speed (5, 3125, 15); // up (first link o up)
position_speed (6, 3750, 15);
delay(400000);




//2nd position
position_speed (8, 5625, 50); // channel 8 ( base rotate to 135)
delay(250000);

position_speed (5, 1250, 15); // down (first link go down)
position_speed (6, 5625, 15);
delay (250000);

position_speed (2, 7100, 40);   //wrist move to 180
delay(450000);


position_speed (3, 2500, 20); // 2nd link go down to 60
delay (300000);

position_speed (1, 900, 30); // grip open
delay(200000);
position_speed (1, 2100, 30); // grip close. smaller d number, bigger
the gap.
delay(200000);


position_speed (3, 3750, 20); // 2nd link go up to 90
delay (200000);


position_speed (5, 3125, 15); // up (first link o up)
```

```
                position_speed (6, 3750, 15);
                delay(400000);


        }

}

void on_off_cmd ( unsigned char channel, unsigned char on_off)
{
        unsigned char first_byte=0;
        first_byte=0b11000000|channel;

        uart_send(first_byte);
        uart_send(on_off);
}

void delay (unsigned long time)
{
        for(;time>0;time--);
}

unsigned char uart_rec(void)
{
        unsigned char rec_data;
        while(RCIF==0);                         //wait for data
        rec_data = RCREG;
        return rec_data;                        //return the data received
}

void uart_send (unsigned char data)
{
        while(TXIF==0);                         //only send the new data after
        TXREG=data;                             //the previous data finish sent
}

void position_speed ( unsigned char channel, unsigned int position, unsigned char
speed)
{
        unsigned char first_byte=0, higher_byte=0, lower_byte=0;

        first_byte=0b11100000|channel;


        higher_byte=(position>>6)&0b01111111;           //position value from 0-
8000 are greater than a byte
        lower_byte=position&0b00111111;
```

```
        uart_send(first_byte);
        uart_send(higher_byte);                 //second byte is the
higher byte of position 0b0xxxxxxx
        uart_send(lower_byte);                  //third byte is the lower
byte of position 0b00xxxxxx
        uart_send(speed);                       //fourth byte is the
speed value from 0-100
}

void patternrec()
{
                if(SW1==0)
                {
                        pattern=1;
                }
                else if(SW2==0)
                {
                        pattern=2;
                }
}
```